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Canada Centre for Mineral and Energy Technology

Centre canadien de la technologie des minéraux et de l'énergie

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91-07099/

VIEWBEAP - AN ADVANCED 3-D GRAPHICAL REPRESENTATION PROGRAM FOR BEAP3D (Sun Version 1.0)

MRL 91-032(TR) March 1991

by

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March 1991

Work on the project was conducted under the auspices of Canada Centre for Mineral and Energy Technology, Energy, Mines and and Resources Canada under a cost-shared contract.

DSS File No. 009SQ.23440-9-9137
CANMET Project No. 23440-9-9139
CANMET Scientific Authority: Y.S. Yu

41 pp

BEAP3D - BOUNDARY ELEMENT APPLICATION PACKAGE
FOR THREE DIMENSIONAL ANALYSIS
OF MINE STRUCTURES
(Sun version 1.0)

The BEAP3D system consists of three separate modules, namely: MINE DESIGNER, BEAP and VIEWBEAP. Three user manuals, published separately, are provided. The three user manuals are listed below:

1- MINE DESIGNER - An Automated Graphical Data Generation Program integrating Numerical Modelling with the Mine Design Process.

2- BEAP - Boundary Element Analysis Program for Three Dimensional Stress Analysis of Mine Structures.

3- VIEWBEAP - An Advanced 3-D Graphical Representation Program for BEAP.

Hardware Requirements:

Minimum Configuration: a Sun Sparcstation computer with colour graphics monitor, 200 megabytes of hard disk, 8 megabytes of RAM.

Suggested Configuration: a Sun Sparcstation computer with colour graphics monitor, 400 megabytes of hard disk, 16 megabytes of RAM.

Software Requirements: SunOS 4.1.1 Operating System, or SunOS 4.1 Operating System plus OpenWindows Version 2.

Reference to this manual should be quoted as follows: "VIEWBEAP - An Advanced Graphical Representation Program for BEAP (SUN version 1.0), Divisional Report MRL 91-032 (TR)"

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1. GENERAL DESCRIPTION

ViewBeap is the result processing module for the three-dimensional boundary element analysis program BEAP. ViewBeap displays mine structures or 3-D boundary element models, checks input data graphically, facilitates the handling of bench mark stress/displacement calculations, and provides graphical representations of analytical results. The OpenWindows version of ViewBeap was developed on a Sun SparcStation, and requires the OpenWindows User Interface which conforms to the X11 protocol.

The users of ViewBeap should be familiar with SunOS and OpenWindows before using the ViewBeap Postprocessor.

The ViewBeap program is designed so that navigation through the program is intuitive even for beginners. All of the program commands are organized in a series of icons.

2. STARTING THE PROGRAM

If you have already installed the BEAP3D software and activated OpenWindows, you should have two tools available. These are:

- Console Window
- File Manager Window

The ViewBeap program can be executed from the console window. Normally, the user would enter:

[path]/viewbeap

Please note that BEAP3D software should be on the user's "PATH". Also ensure that the data files required to run ViewBeap should be in the user's directory (refer to Section 10.4 for details).

The full command line with various options is as follows:

viewbeap [-h] [-l lx,ly,lz] [-3 w,d] [-x m507path] [dir]

The description of the command line options are given below:

-h Lists help for the available options

-l Light source definition
Light source is defined as the direction of a vector in space. lx, ly, lz are the direction numbers. The default direction numbers are: 1,2,3.

An example of the option is shown below:
-l 0,0,1

-3 3-D Glass Parameters.
This option may be used to customize the stereoscopic vision settings for each individual user. Two parameters, w and d, are needed. w is the width between eyes, the default value is 50. d is the distance from the eyes to the screen, the default value is 1000.

-x This option defines the path of the program module m507 which is responsible for stress calculations. This option is required only when user wishes to display stresses from a resultcube or resultplane(s).

dir dir is the directory name for the current problem session.
BEAP3D uses a directory for each problem session. The default is the current directory.

3. MAIN WINDOW

3.1 FUNCTIONAL DEFINITIONS

The first window which shows up on the screen is referred to as the ViewBeap Main window. The components of this window are illustrated below:

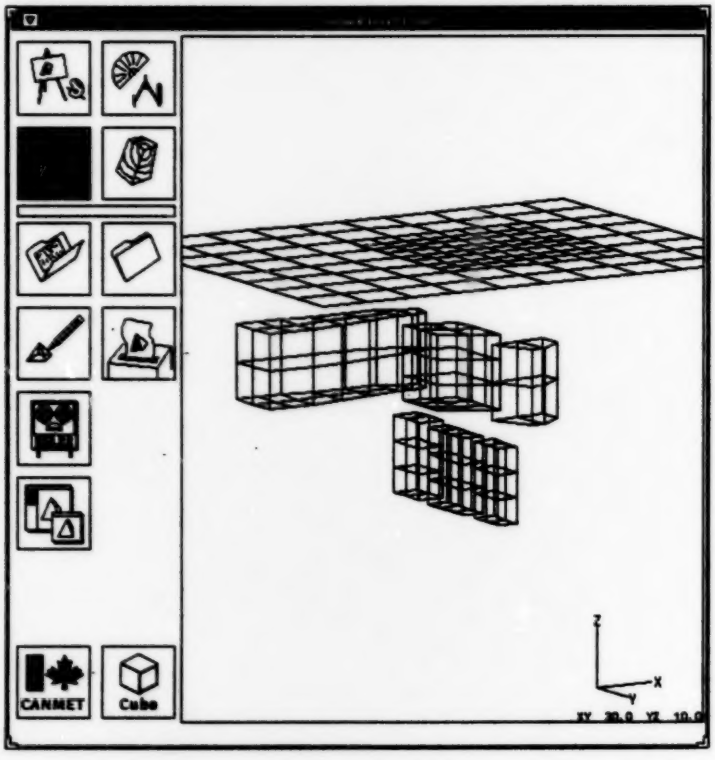


Fig 3.1 Components of the ViewBeap Main Window

The main menu contains four items that remain present throughout the run of the program. The bottom portion of the menu region is referred to as the submenu area. This section will change according to the main menu options selected by the user.

The graphics display area is the section where the mine geometry is displayed. Once the user completes the graphics related functions, the modified image will be displayed in this region.

3.2 HOW TO USE THE MENUS

Viewbeap has been developed to be user friendly and easy to use. To accomplish this, ViewBeap is designed around a simple and consistent menu system. All menu items appear as rectangular icons, neatly organized on the left hand side of all major windows. There are three different types of menu items:

- Activation Items - simply click on the item to perform its task.
- On/Off Items - click on the item to turn the feature on or off. The image on the item appears as black when off and white when on.
- Choice Items - clicking on the item will change the item to the next choice. Optionally the user can click and hold the left button on the item while cycling through the choices with the right button.

3.3 MENU STRUCTURE

The main menu area consists of four menu items which in turn activates various sub menu items. The four main items of the program are listed below:

DISPLAY MENU

The Display submenu allows the users to access different graphics speed options, three dimensional viewing and select shading types.

GEOMETRY DEFINITIONS MENU

The Geometry Definitions submenu enables the users to access the functions required to manipulate the image such as zooming, panning, or rotations.

FILE MENU

The File submenu allows the users to access various file operations such as saving, printing, creating animation sequences and activating the preprocessor.

RESULT MENU

The Result submenu allows the users to access functions which are used for displaying stresses, defining stress planes and parameters, etc.

3.4 FILE MENU ITEMS

Once selected, the following sub menu items will be available to the user:

OPEN FILE

This menu item allows the user to open a new model. The user is prompted for the name of the directory that contains the problem set. The default directory is "." to signify the current directory. For more information on the data files see Section 10.4.

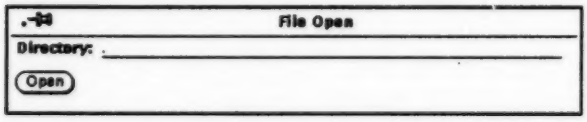


Fig 3.2 File Open Dialogue Box

FILE SAVE

This menu item should be used in order to save the changes made during a session. All of the editable data used by ViewBeap is stored in the memory, therefore, the changes you make during a work session will not be saved unless this menu item is used.

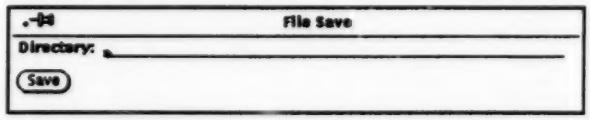


Fig 3.3 File Save Dialogue Box

PREPROCESSOR

This menu item will activate Mine Designer - the preprocessor module where the user can draw and edit the mine geometry. The preprocessor module uses its own window and will be described in a separate manual.

PRINT

This menu item will allow the users to print the graphics image as displayed in the main window. The print dialogue box is illustrated below:

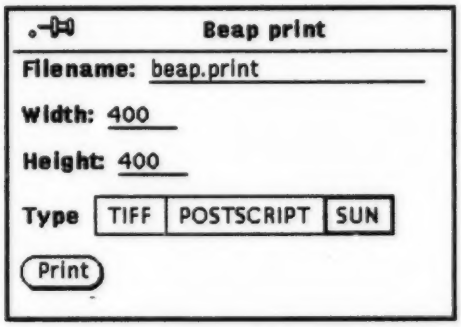


Fig 3.4 Print Menu items Dialogue Box

ViewBeap does not send images directly to the printer; the images are instead sent to a file of a selected format. This gives the user the best flexibility especially when there is no standard for printing colour images. The image sent to the file will have the same appearance as the image currently being viewed in the main window. The aspect ratio of the image will always be 1:1.

The user is required to enter the width and the height of the image. The available file formats are TIFF, Colour PostScript and Sun Rasterfile.

ANIMATE

Visualizing 3-dimensional geometry and results is a difficult task. It is often advantageous to move about a scene to get a real understanding of what you are looking at. ViewBeap's wire frame rendering has been designed to be reasonably responsive for real-time movement through a scene, however, displaying contours takes too long to be interactive. For this reason ViewBeap includes an animation feature that will record images and then allow fast playback. The animation feature is not intended to be a movie studio, however, it is often useful as a demonstration tool to familiarize people quickly with mine data.

The animate menu item will activate the following dialogue box. The dialogue box is initially set up for One by One recording discussed below and will expand if the Open Log button is selected.

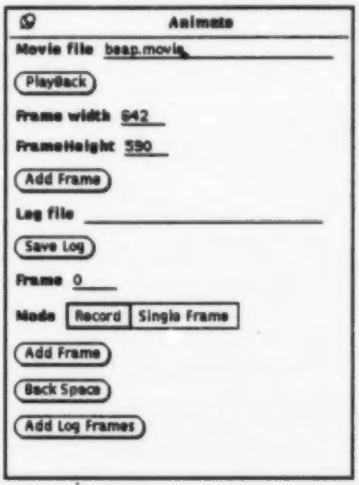


Fig 3.6 Animation Dialogue Box

Animation sequences can be recorded in two ways: one by one frame storage or using log files.

One by One

To record frames one at a time, the user must: set the movie filename, set the width and height of the images and then press the Add Frame button every time the image in the main window is to be appended to the movie.

Log Files

Log files allow the user to pre-record the orientation of the scene in wireframe mode, change to the viewing mode that best suits the movie and then let the computer "crunch" for a while to produce the movie.

The following is a list of procedures illustrating the normal use of log files.

Procedures for log files:

To start a new log file :

- clear the "Log File" text field.
- press the "Open Log" button.

To load an existing log file:

- fill the "Log File" text field with the desired filename.
- press the "Open Log" button.

To save a log file:

- fill the "Log File" text field with the desired filename.
- press the "Save Log" button.

To abort a log file :

- clear the "Log File" text field.
- press the "Save Log" button.

To add the current orientation of the main window to the log file:

- set the "Mode" choice to "Single Frame".
- press the lower "Add Frame" button.

To remove the last frame from the log file and correct the main window:

- press the "Back Space" button.

To record a series of frames for the log file:

- set the "Mode" choice to "Record".
- move about in the main view using any of the available geometry menu features (watch the Frame indicator).
- set the "Mode" choice to "Single Frame" when done.

To add the frames in the log file to the current movie:

- set the "Frame width" and "Frame Height" text fields
- set the "Movie file" text field
- ensure that the main window has the correct appearance (shading speed, image type, etc.).
- press the "Add Log Frames" button and wait until the number displayed at the bottom of the dialogue box reaches the number of frames.

Log files may also be edited using a text editor to perform more advanced animations. The format of the log files can be found in section 10.4.1.

AUXILIARY

The Auxiliary menu item is used to freeze and save a specific image inside an auxiliary window. This feature can be useful for comparing the active screen with another screen image processed earlier.

CANMET

Work on the project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy Mines and Resources Canada.

DSS File No. 009SQ.23440-9-9137
CANMET Project No. 23440-9-9139
CANMET Scientific Authority: Y. S. Yu

CUBE

The ViewBeap post-processor was developed, under contract to CANMET, Energy Mines and Resources Canada, by Cube Systems Consulting Services Inc. in Ottawa, Ontario, Canada.

3.5 DISPLAY MENU ITEMS

The Display sub menu allows the user to access commands which will effect the appearance of the graphics image. The available menu items are listed below:

STEREOSCOPIC IMAGE

This menu item can be used to view the image in a three-dimensional stereoscopic manner. You must use the supplied 3-D glasses to be able to see this effect. When viewing complicated geometries, this menu item becomes an important tool to realize depth within the image.

Stereoscopic imaging does not work while displaying stresses. You should also note that, the clarity of the 3-D vision depends on the initial options selected while activating the ViewBeap program as described in Section 2.

SHADING SPEED

The shading speed menu item has three choices:

- Fast graphics (rabbit mode)
- Slow graphics (turtle mode)
- Slower graphics (snail mode)

The ***fast graphics*** choice is primarily used to orient the model. Some approximations are made that may lead to visual errors in the image (the back of a stope showing through the front), however, the increase in speed allows for interactive movement. Once the user is satisfied with the final form of the image, a slower but more accurate representation for the model may be chosen. **Stress contours will not appear in fast mode.**

Slow graphics is usually sufficient for final images, but it can take up to 30 seconds for very complicated images. Hidden and intersecting faces appear properly. All stresss contours appear, however, the shape of the contours may only be approximate.

The ***slower graphics*** choice produces the same results as the ***slow graphics*** except that special attention is given to the shape of stress contours. The time required for this mode can range from 1 to 2 times the time needed for slow graphics.

IMAGE TYPE

The image type has four choices from which to select. These choices are:

- Wire frame
- Wire frame with numbers
- Solid colour coded
- Solid shaded

Wire frame is the default choice. Most of the movement related functions should be performed in this model, which is the most convenient and fastest mode in ViewBeap.

For reference purposes, it is possible to display the wire frame with numbering, i.e., element numbers and node numbers. The numbers in red correspond to the nodes while the numbers in black to the elements.

The solid colour coded choice is generally used to identify between different objects within the mine geometry. Initially all elements are coloured green. The Edit Element Colours menu item must be used to change the colour of the elements.

The fourth choice is solid shaded faces. The faces are coloured to give the appearance of a white light source emanating in defined direction on green faces. The direction of the light source may be changed using one of the startup options discussed in Section 2.

EDIT ELEMENT COLOURS

When using the solid color coded choice discussed above, it is necessary to change the colour of the faces. A separate window is used for this purpose and is discussed in Section 4. The menu item will activate this window.

TEXT LEGEND

This menu item will activate a text legend on the graphics screen which contains two user defined lines of text and other information detailing the current orientation, stresses displayed as well as any warnings the viewer should be aware of. The two user defined lines of text as well as the location of the text legend may be changed using the LEGEND DEFINITION menu item discussed on page 16.

HIDE ELEMENTS

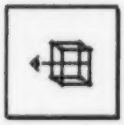
This menu item will remove any tagged hidden objects from the main and other windows. The objects can be tagged hidden using the HIDE EDIT menu item. This procedure can prove to be useful if the graphics image is too complex and the section to be displayed is a small portion of the overall geometry.

HIDE EDIT

This menu item will activate a new window where elements can be tagged as being hidden. For more information on hiding elements see Section 5.

3.6 GEOMETRY SUBMENU

The Geometry submenu contains menu items used to orient the model in the main window. Through this submenu you can access the following menu items:



VIEW MODE SELECTION

ViewBeap can project the image on the screen in one of two ways:

- Isometric mode
- Perspective mode

Isometric mode

This mode simply removes the depth from the scene giving a very rectangular appearance to the model. Isometric viewing is best suited for judging distances and seeing the model as a whole. The orientation of the view can be changed by: rotating, zooming and panning the image.

Perspective mode

Using a perspective projection the viewer is placed within the model. Orienting the viewer becomes somewhat more complicated than in the isometric projection. The orientation of the view can be changed by: rotating, moving the eye position and moving the point of interest.

ROTATE

This menu item will allow you to rotate the image. Rotations can be done by clicking the left mouse button inside the graphics image, and moving the mouse, to bring the object to the desired orientation, without releasing the left mouse button. Once the image is positioned in the way you require, you can release the mouse button. The image will then be displayed in the new rotated configuration.

ZOOM

This menu item can be used to zoom in and out of the graphics image. Zooming can be performed by selecting an area where you wish to zoom using the left mouse button. If you wish to zoom out you should use the same operation by using the right mouse button.

PAN

Moving the graphics image can be performed by selecting the pan menu item. When this menu item is selected you can move the mouse pointer inside the graphics area and click on a point of the image. The user then translates this point by dragging the mouse (without releasing the mouse button) to the new location. When the mouse is released, the entire image is redrawn with this translation.

SET EYE POSITION AND POINT OF INTEREST

When perspective mode is select, this menu item will appear. It will activate a window which will allow the user to graphically change the position of the viewer and the point of interest in the scene. For more information see Section 6.

3.7 RESULT PROCESSING

The Result Processing submenu contains menu items related to the viewing of stress and displacements:

DEFINE RESULT REGION

This menu item will activate a new window, where you will be provided the capability to define regions for which the results (stresses and displacements) are to be calculated by the DIVIDE program.
A detailed description of the Result Regions Definition window will be given in Section 7.

DEFINE RESULT PLANE

This menu item will activate a new window from which to define result planes. These planes are the only means of viewing the results within the result cubes. A detailed description of the Result Plane Definition Window is given in Section 8.

HIDE OR SHOW RESULT PLANES

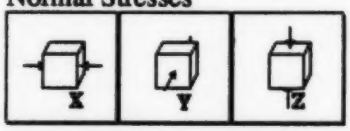
This menu item is similar to the hide menu item in the Geometry menu. If the boundary element model is large and complex, it may be difficult to identify and interpret the results as they are displayed on the screen. Using hide menu item, you can turn off previously defined result planes and look at one or several of these planes at a time.

This menu item will create a new window which is referred to as the Hide Result Planes window. A detailed description of this window will be discussed in Section 9.

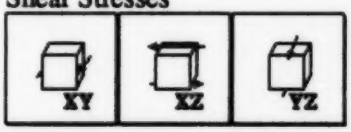
DEFINE STRESS TYPE

This menu item is used to select the current stress type. The available types of stresses and user-defined quantities are summarized below:

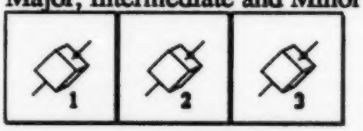
Normal Stresses



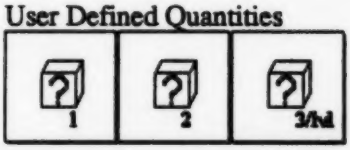
Shear Stresses



Major, Intermediate and Minor Stresses

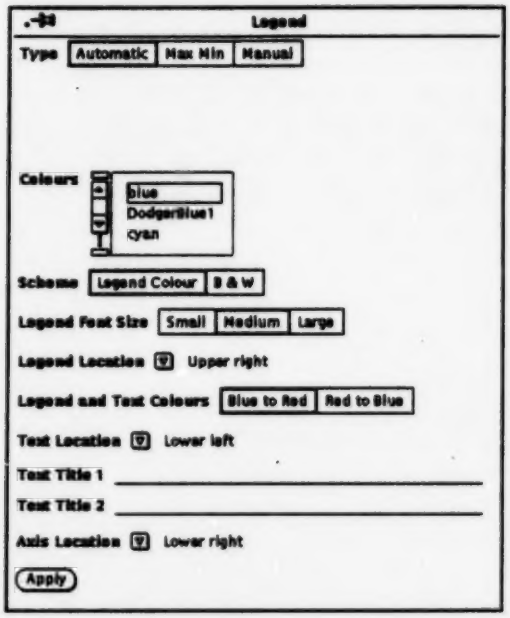


User Defined Quantities



LEGEND DEFINITION

Stress legend is used to define the stress levels and colours corresponding to the defined stress intervals as well as the appearance of stress and text legends. The stress legend menu item will display the following dialogue box:



Once the options are set, the user can click on the apply button to invoke the changes to the legends.

ELEMENT STRESS VIEW TYPE

Through this menu item the user can select the type of results to display. There are 6 options available:

No results display.

Conforming stress contours.

Non-conforming stress contours.

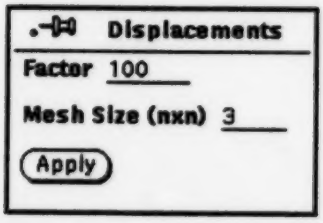
Stress display according to the center value.

Deformed structure.

Deformed structure with non-conforming stresses.

SCALE AND DEFINE THE MESH SIZE

This menu item is used to define a scaling factor for the displacement display and the mesh size is used for displacements and non-conforming stress display. The following dialogue box will appear:



MINING STEP NUMBER

The BEAP3D system allows the user to define multiple mining steps for a given model. This menu item is used to select one of the available mining steps for viewing. All geometries not pertaining to a given mining step will be hidden. The results will be reloaded for the new mining step.

Mining steps 1 through 10 are currently available. Mining step 1 is the default.

4. SET ELEMENT COLOR WINDOW

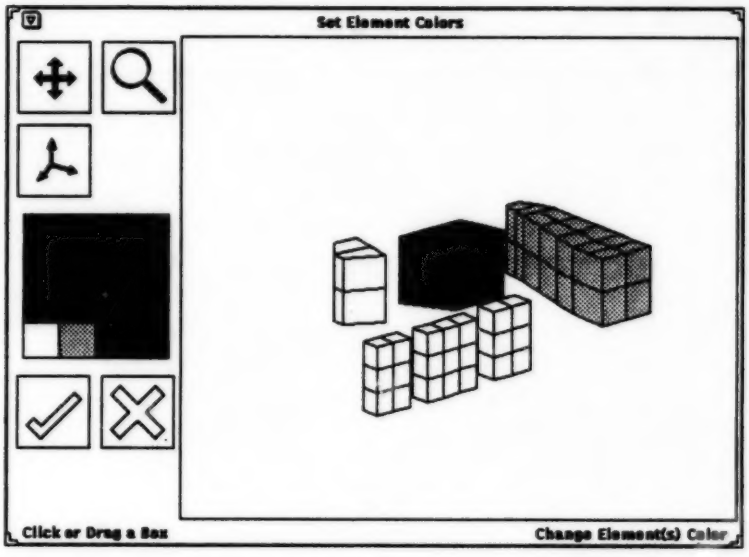


Fig 4.1 Set Element Color Window

For identification reasons, it is often useful to colour code elements. These colours are only used by the main window when the image type is set to solid colour coded (see page 12).

The colour pad menu item determines how selected elements will be coloured. The user should select elements by either:

- selecting individual elements by simply clicking on the elements or,
- selecting a group of elements by clicking and dragging a box that surrounds the elements.

MENU ITEMS

ROTATE

Rotate to improve visibility. See page 14

ZOOM

Zoom in or out to improve visibility. See page 14

PAN

Move to improve visibility. See page 14

OK

When all functions are completed you should use the OK menu item to close the window and accept the changes.

CANCEL

This menu item should be used to cancel the current operation and close the window.

5. EDIT HIDE WINDOW

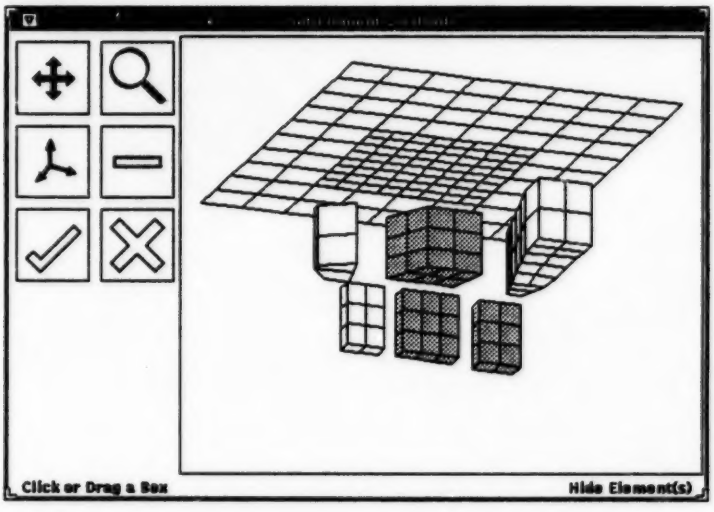


Fig 5.1 - Edit Hide Window

This window is used to hide elements of the graphics image to get an uncluttered picture of the region which you wish to work on. You may find this useful especially if the geometry of the problem is complicated.

In this window the elements to be hidden are coloured grey. When the Ok menu item is selected these elements will not be visible in all other windows.

The hide(-)/unhide(+) menu item determines how selected elements will be affected. The user should select elements by either:

- selecting individual elements by simply clicking on the elements or,
- selecting a group of elements by clicking and dragging a box that surrounds the elements.

MENU ITEMS

ROTATE

Rotate to improve visibility. See page 14.

ZOOM

Zoom in or out to improve visibility. See page 14.

PAN

Move to improve visibility. See page 14.

HIDE(-)/UNHIDE(+)

This menu item indicates the operation that would occur when elements are selected.

OK

When all functions are completed you should use the OK menu item to close the window and accept the changes.

CANCEL

This menu item should be used to cancel the current operation and close the window.

6. SET EYE WINDOW

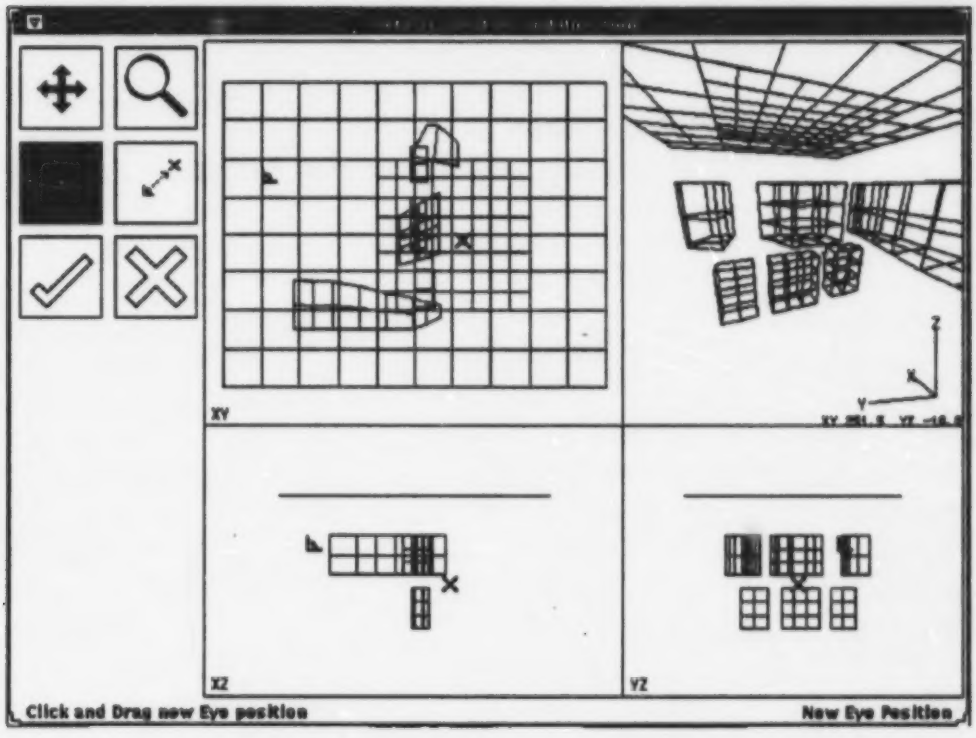


Fig 6.1 - Set Eye window

This window is used to set the eye location and eye destination for the perspective viewing mode. The eye location and eye destinations are illustrated by two icons: an eye and a cross, respectively. By moving these in any of the three planar views, you will be able to change the display orientation. The new orientation will be displayed in the top right window.

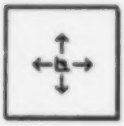
MENU ITEMS

ZOOM

Zoom in or out to improve visibility. See page 14.

PAN

Move to improve visibility. See page 14.



SET EYE LOCATION

This menu item is used to select the viewers position. The user may then click and drag the eye icon to the desired location in one of the planar views. The resulting scene is animated in the fourth view.

SET EYE DESTINATION

This menu item is used to select the location that the viewer is looking at. The user may then click and drag the cross icon to the desired location in one of the planar views. The resulting scene is animated in the fourth view.

OK

When all functions are completed you should use the OK menu item to close the window and accept the changes.

CANCEL

This menu item should be used to cancel the current operation and close the window.

7. DEFINE RESULT REGIONS WINDOW

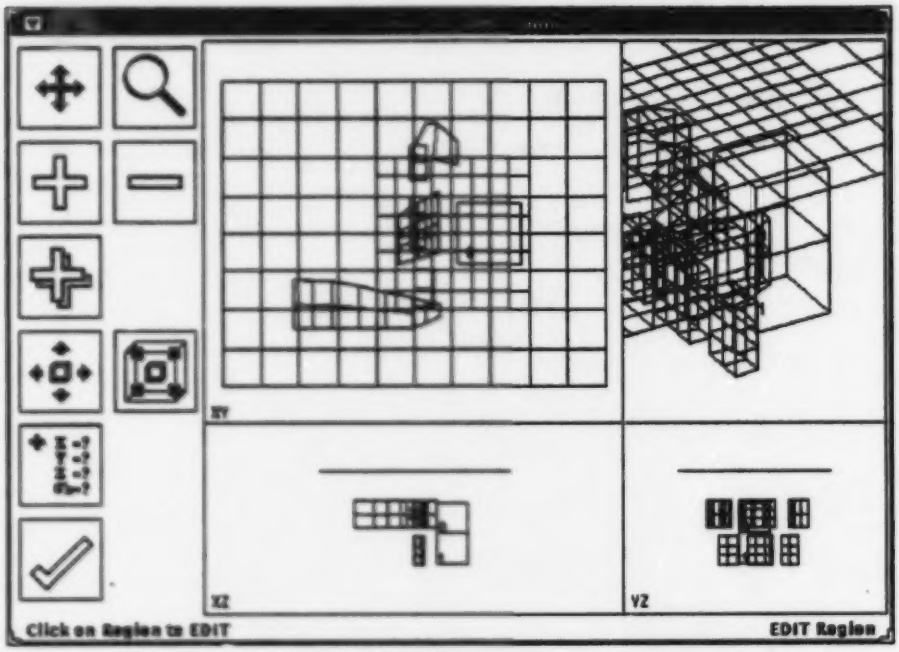
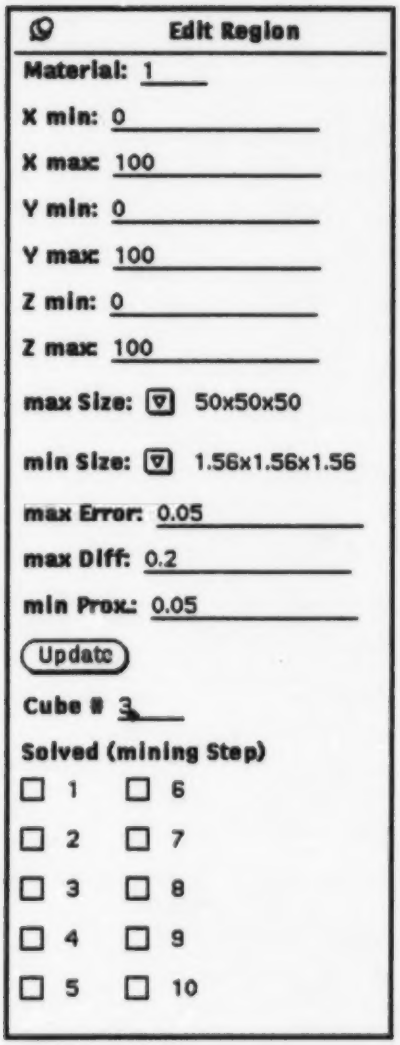


Fig 7.1 - Result Regions Window

This window is used to define the regions for which volumetric stress calculations are to be performed. These regions (also called result regions or resultCubes) are represented by brick shaped objects in space that can be located and sized to encompass areas of interest. The regions can be overlapping if required but it is not suggested as this will increase the time required for finding the solution. The DIVIDE program, which is discussed in Section 10.5, is used to fill the result cubes with data. The reader should take some time to become familiar with the workings of DIVIDE because of its importance to viewing volumetric stress in VIEWBEAP.

Each result region is shown in the views as a red block with an identification number in the lower left corner. The three views labelled XY, XZ and YZ are used to graphically manipulate the regions while the fourth view shows a three dimensional look at the regions to give the user a better feel for the orientation of the regions.

Each result region has an individual set of parameters that describe the size and shape of the region, the criteria required for finding its data and indicators to show the extent of the solution. The dialogue box below will appear during various operations to change these parameters. The information will belong to the region that was most recently selected. The user may select a region for inspection at any time by simply clicking on the image of the region in one of the views. The update button must be pressed to keep any changes that were made in the dialogue box.



- material represented by the region (typically 1)

- location and size of the region

- parameters for DIVIDE

- identification number

- status of the solution

MENU ITEMS

The following menu items are available to manipulate the views and result regions:

ZOOM

Zoom in or out to improve visibility. See page 14.

PAN

Move to improve visibility. See page 14.

CREATE A RESULT CUBE

A new result cube is created in the center of the model with an appropriate size and parameters for further modification. The information dialogue box reflects the new cube.

DELETE A RESULT CUBE

The user is prompted to click on the cube that is to be deleted with the left mouse button. The center mouse buttor will cancel the operation.

MOVE A RESULT CUBE

A result region can be moved graphically in any of the XY, XZ or YZ views. The user is prompted to click and drag a cube to the required location with the left mouse button. The center mouse button will cancel the operation before and during dragging. The information dialogue box dynamically reflects the altered cube and the apply button is automatically invoked when done.

DUPLICATE A RESULT CUBE

This menu item functions similarly to the move menu item except that a new cube is created with the same parameters in a different location.

SIZE A RESULT CUBE

A result region can be sized graphically in any of the XY, XZ or YZ views. The user is prompted to click on and drag out the shape of a cube with the left mouse button. The center mouse button will cancel the operation before and during dragging. The information dialogue box dynamically reflects the altered cube and the apply button is automatically invoked when done.

SHOW STRESS AT A POINT

This menu item will activate a dialogue box which lists various stress information related to a specified point within the result cube. For more information see Section 10.7.

OK

When all functions are completed you should use the OK menu item to close the window and accept the changes.

8. DEFINE RESULT PLANES WINDOW

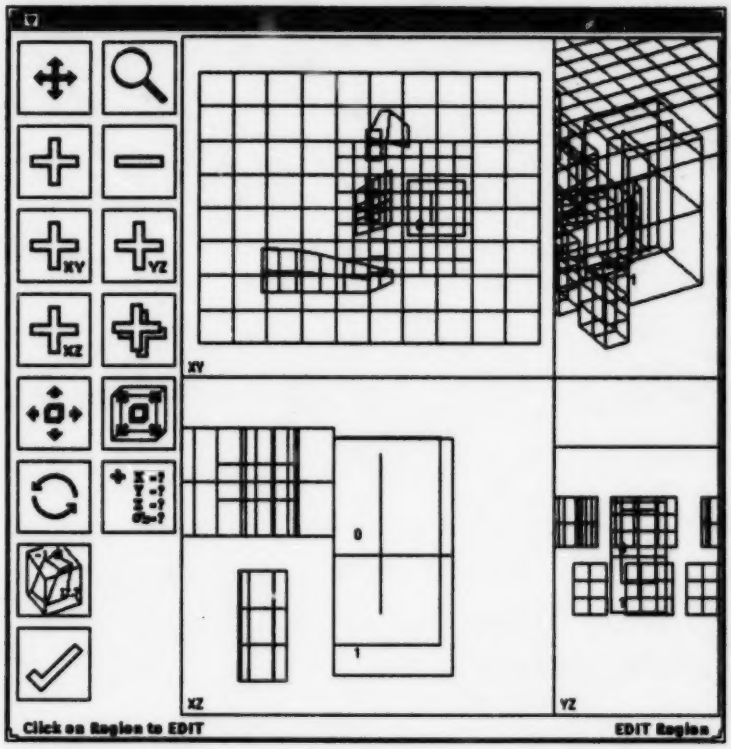


Fig 8.1 - Result Planes Window

This window is used to define planes for stress display. The defined planes will cut the result cubes and stresses on the surface of the planes will be displayed. The result planes can have height, width and thickness producing six sided bricks. Separate subdivisioning values are available for the three dimensions to set the required grid spacing.

The result planes in the window can easily be identified by green lines. If you wish to hide some of these planes for viewing convenience, you should activate the Hide Planes Window as described later.

You can also get detailed information related to the result plane. This can be performed by clicking on the result plane region for which you wish to get information. A dialogue box will appear listing information relevant to the selected result plane.

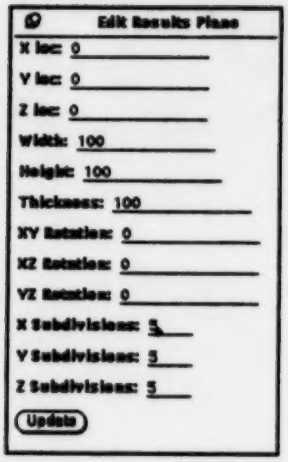


Fig 8.2 - Detailed stress information for result planes

ZOOM

Zoom in or out to improve visibility. See page 14.

PAN

Move to improve visibility. See page 14.

CREATE A RESULT PLANE

These menu items should be selected when the user is going to define a new result plane. The subscripted letters allow the user to create two dimensional planes oriented properly on the required axes.

DUPLICATE A RESULT PLANE

This menu item functions similarly to the move menu item except that a new plane is created with the same parameters only in a different location.

DELETE A RESULT PLANE

This menu item should be selected when you wish to delete an existing result plane. Stress calculations will not be displayed for deleted result planes.

MOVE A RESULT PLANE

A result plane can be moved graphically in any of the XY, XZ or YZ views. The user is prompted to click and drag a plane to the required location with the left mouse button. The center mouse button will cancel the operation before and during dragging. The information dialogue box dynamically reflects the altered plane and the apply button is automatically invoked when done.

SIZE A RESULT PLANE

A result plane can be sized graphically in any of the XY, XZ or YZ views. The user is prompted to click on and drag out the shape of a plane with the left mouse button. The center mouse button will cancel the operation before and during dragging. The information dialogue box dynamically reflects the altered plane and the apply button is automatically invoked when done.

ROTATE A RESULT PLANE

A result plane can be rotated graphically in any of the XY, XZ or YZ views. The user is prompted to click on and drag out the orientation of a plane with the left mouse button. The center mouse button will cancel the operation before and during dragging. The information dialogue box dynamically reflects the altered plane and the apply button is automatically invoked when done.

SHOW STRESS POINT

This menu item will activate a dialogue box which lists various stress information related to a point within the result plane. For more information see Section 10.7.3.

SHOW MAX MIN VALUES

This menu item is used to print the maximum and minimum stress values for the selected stress type. These values are printed on the graphics image for your convenience. If you wish to see these values clearly you can zoom into a region until the text does not overlap.

DEFINE STRESS TYPE

This menu item is used to select the type of stress shown by the SHOW MAX MIN VALUES menu item above. You can toggle between the nine types of stresses and the three user-defined quantities for display. For a description of the types of stresses refer to page 15. This menu item will only appear if the SHOW MAX MIN VALUES menu item is activated.

OK

When all functions are completed you should use the OK menu item to close the window and accept the changes.

9. HIDE PLANES WINDOW

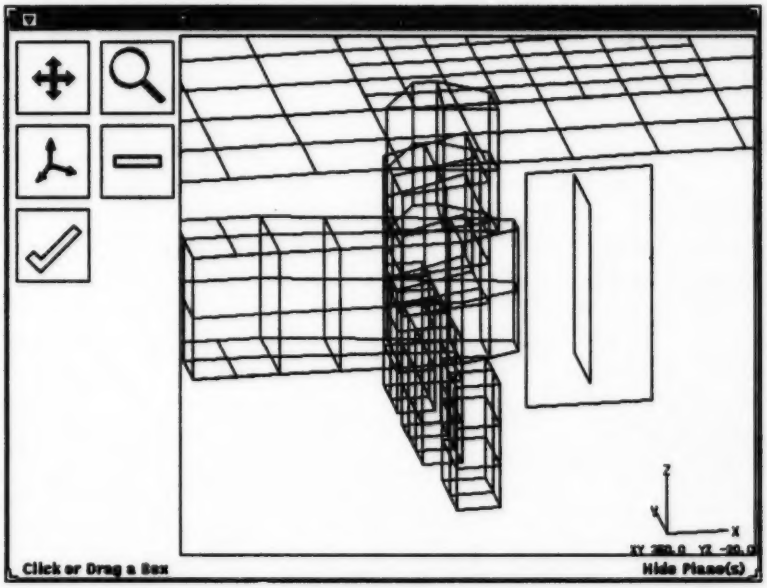


Fig 9.1 - Hide Planes Window

This window is used to hide result planes defined using the result planes window. You may find this useful especially if the geometry of the problem is complicated and you wish to see the stresses for a specific result plane only. This menu item will not delete the previously defined result planes, but simply hide them from the display.

In this window the planes to be hidden are coloured gray. When the Ok menu item is selected the planes in the main window will not be visible.

The hide(-)/unhide(+) menu item determines how selected planes will be affected. The user should select result planes by either:

- selecting individual planes by simply clicking on the planes or,
- selecting a group of planes by clicking and dragging a box that surrounds the planes.

MENU ITEMS

ROTATE

Rotate to improve visibility. See page 14.

ZOOM

Zoom in or out to improve visibility. See page 14.

PAN

Move to improve visibility. See page 14.

HIDE(-)/UNHIDE(+)

This menu item indicates the operation that would occur when elements are selected.

OK

When all functions are completed you should use the OK menu item to close the window and accept the changes.

CANCEL

This menu item should be used to cancel the current operation and close the window.

10. TECHNICAL DESCRIPTIONS

10.1 DESCRIPTION OF THE SYSTEM

ViewBeap, the post-processor for the boundary element analysis program BEAP, represents the state-of-the-art in graphics software design in present day computer systems. The graphics system compliments the analysis program, which provides the users with an excellent display of the mine model for analysis and visual representations of the analytical results. This provides a useful tool for use by mining engineers in mine planning and ground control.

10.2 DESIGN PLATFORM

The program was developed using a SUN Sparcstation with 8 megabytes of RAM and 200 megabytes of hard disk storage with a graphics subsystem using a 16" colour monitor.

The system was simultaneously developed in two environments. OpenWindows for Sun computers and Microsoft Windows 3.0 for MSDOS based computers. The program was entirely written in C and the coding was designed and grouped in such a way that easy porting can be possible to environments such as Microsoft Windows and OS/2 Presentation manager.

10.3 GRAPHICS SPEED CONSIDERATIONS

The graphics system was designed to use the following display modes:

Fast Mode (rabbit mode): This is very fast. It is used for preliminary viewing and positioning the model.

Slow Mode (turtle mode): This is considerably slower than rabbit mode. It is used for drawing contours and showing plate intersections. This may not be entirely accurate however.

Slower Mode (snail mode): This can take as much as double the time as turtle mode. It, however, gives completely accurate results.

10.4 BEAP DATA FILES

The BEAP3D system requires that each model (sometimes called a data set) have its own directory to contain the required files. There are numerous files used by the BEAP3D system however only a few are used by ViewBeap. The files used by ViewBeap are:

geom1.dat	- the principle geometry file
geom2.dat	- element information file
elesol.<s>	- element surface results (<*s*> is the mining step)
resultPlanes	- result plane geometry file
resultCube<n>	- result region geometry file (<*n*> is the id number)
resultCube<n>.<s>	- result region results file (<*s*> is the mining step)

ViewBeap may also create at the users request several other types of files. The location of these files do not necessarily have to coincide with the directory that contains the geometry files. Therefore, the user will be prompted to enter the full name of the file in such cases. The circumstances where the user will be asked for full file names are listed below:

- Printing - all printing is done to files.
- Animation movie file - see note below.
- Animation log file.

Note: although the list of frames used in the animation is saved in this file, the actual images are always stored in a "./frames" directory. This directory is created if not already present. This will probably be changed in the future.

10.4.1 Animation Log File Format

The animation log files are simple text files that describe the orientation of multiple frames. Each frame is described by a series of lines in the file that define the difference between the last frame and the next. Each line has a function name at the beginning and any required values after it. The valid functions are as follows:

• POS <*x*> <*y*> <*z*>	- change the eye position
• MODE <*mode*>	- viewing mode (0 isometric, 1 perspective)
• SIZE <*size*>	- zooming size (10000 whole model, 5000 half)
• PAN <pan_x> <pan_y>	- panning amounts (same as SIZE)
• DIR <ang_{xy}> <ang_{yz}>	- rotations (in degrees)
• LOOKAT <*x*> <*y*> <*z*>	- rotations set by looking from POS to *xyz*

- FOLLOW <n_{ahead}> - rotations set by looking at the POS of the (current+n_{ahead})th frame. The frames are assumed to form a loop so that if there are not enough frames remaining, the POS values for frames at the beginning of the log file are used. n_{ahead} set to zero turns off the follow feature.
- FRAME - produce a frame

To produce an example of a log file, simply record a short set of frames as described on page 9 and then view the log file with a text editor.

10.5 DIVIDE PROGRAM

To be able to represent contours inside the rock mass, the user will have to define two graphic entities required by **VIEWBEAP**; a ***ResultCube*** and a ***ResultPlane***.

To invoke the program, the following command is required:

divide [path]resultCube<#> [m507c.e] [-1 user1.e] [-2 user2.e] [-3 user3.e]

where:
- # is a unique integer which identifies the result file
- m507c.e is the pathname of a "results program"
- user#.e is the pathname of a "user definition program"

10.5.2 DEFINITION OF A RESULTCUBE

A ResultCube is a 3-D Block which is defined by the three coordinates axes. The (block) can contain only one subregion type. A companion program of **VIEWBEAP**, **DIVIDE**, will be called to decide where benchmarks have to be computed to represent stress contours at the level of accuracy requested by the **VIEWBEAP** user. For this purpose **DIVIDE** recursively subdivides the initial cube or block into 8 subcubes (each containing 8 benchmark locations) until subcubes are totally inside or outside an excavation, or until the level of accuracy has been reached. The level of accuracy is set by giving proper values to the following variables defined for each ResultCube:

- **Minimum level of Cube subdivision:**
  DIVIDE will subdivide the ResultCube based on the minimum level using octree subdivision even if acceptable accuracy has been

reached. The user should define this level of subdivision to ensure that an excavation will not be entirely contained within one of the resulting sub-cubes.

- **Maximum level of subdivision:**
  DIVIDE will stop the subdivision of the ResultCube when the maximum level is reached even if accuracy has not been attained, or even if part of some subcubes are still inside the excavation. **Warning**: if the maximum level is too high it can lead to unacceptable computation times.

- **Maximum error:**
  DIVIDE will continue to subdivide, based on the following test: Interpolation is performed at the centre of the subcubes. The interpolated value is compared to a computed value, and if the difference between the two is higher than the specified maximum error, the subdivision will continue.

- **Maximum difference**
  This parameter specifies the ratio between the maximum and minimum stresses for each component of stresses found inside a cell or subcube (xmx-xmn), and the maximum and minimum stresses for the same component of stress found across the entire Resultcube (xmax-xmin). Suppose the maximum difference mxdif = 0.2, then if
  (xmx - xmn)/(xmax - xmin) > mxdif, the cell in subcubes will be subdivided until
  (xmx -xmn)/(xmax - xmin) ≤ mxdif.

  For example, if the range of the major principal stress found across the entire Resultcube is 10, and the maximum difference is specified as 0.2, a cell within the resultcube will be further divided until the range of the major principal stress found inside the cell is less than or equal to 2, ie. 2/10 = 0.2.

  For most cases, this parameter should be set to 1.0. to deactivate this feature

- **Minimum proximity ratio:**
  Sometimes the solution gives inaccurate results for benchmarks computed too close to an element. **DIVIDE** will consider a benchmark invalid if located at the distance smaller than the minimum proximity ratio multiplied by the largest dimension of the closest element. Tests performed on BEAP have shown that

optimal values for this parameter are between 0.05 and 0.2. A very small value can display inaccurate results for locations too close to the element surface.

When computing a resultCube, **DIVIDE** will place, by default, the maximum error found in the user defined field #2 of the stress component menu. The same level of subdivision reached will be used in the user-defined field #3. This is only true if no user-defined program has been initiated in the command line for user-defined fields 2 and 3. (see more about user-defined fields)

Module **M507D** is used in conjunction with module **DIVIDE** to calculate stresses inside a ResultCube or in conjunction with the post-processor to define interactively the location of the benchmarks.

The ResultCube for mining step 1 can be computed using the following command:

path/divide ResultCube0 -s1 *path*/m507d.e

where,

path is the path of the directory where BEAP3D has been installed;

ResultCube0	user-specified 3-D block containing the results;
-s1	Mining step number 1.

Most of the parameters of the ResultCube can be modified by changing the command line. To access the module DIVIDE, user needs to type:

path/divide

For computing interactively the benchmark stresses in VIEWBEAP, enter following command:

path/viewbeap -x *path*/m507d.e

10.5.3 DEFINITION OF A RESULTPLANE

When a ResultCube has been processed by **DIVIDE** a user can define a ResultPlane located inside the ResultCube for the display of stress contours. The stresses or user-defined values will be displayed on the surface of the ResultPlane(s). ResultPlanes created by **VIEWBEAP** could be saved for a future session by using the save file command of **VIEWBEAP**.

Users can find more information about the ResultPlane in the *DEFINE ResultPlane Window* section of the **VIEWBEAP** user's manual.

10.5.4 USER-DEFINED FIELDS

A user-defined program, **coulomb,** has been created to perform one of the user-defined functions. This program reads in a file called coulomb.dat, and calculates the factor of safety according to the Mohr-coulomb failure criteria. This file has the following format:

Mat_number, coh, frict

.

.

0,0,0

where,

- *Mat_number* is the region number of a model where the calculation is to be performed;
- *coh* is the cohesion of material for the specified region; the unit used in the analysis should be consistent.
- *frict* is the friction angle in degrees.

The source for this program is given in the file coulomb.f. This provides an example for the user to create additional programs to evaluate other user-defined values such as safety factors based on the Hoek/Brown empirical failure criterion.

The command required to call this program for specifying user-defined field 1 and for the mining step 2 in a ResultCube which has already been computed by **M507D** is :

path/divide -s2 -1 *path*/coulomb ResultCube0

where

-s2	mining step number 2.
-1	user-defined field #1.
coulomb	user-defined program to calculated the factor of safety based on Mohr-Coulomb failure criterion.
ResultCube0	user-specified 3-D block containing the results.

Notes:

- in the current version no program has been created to represent user-defined field on the element.
- computation of user-defined field can be performed in the same time when the stress computation is done by **M507D**

10.6 KNOWN LOSS OF PRECISION

Loss of precision occurs when improper handling of the event where parts of a result region are inside and outside of an excavation and the maximum level is reached. Currently the program assigns the stress value of the closest face to the interior points thus causing confusion at the element faces.

10.7 STRESS REPRESENTATIONS

Visual representation of the intensity of the stress on elements of the constructed model constitutes the main function of ViewBeap. All interpolation refers to linear interpolation between points of known stress. Linear interpolation is used in determining the stress contours between points of known stress within a region.

There are three different methods for representing stress within VIEWBEAP: element stresses, planar stresses and point stresses.

10.7.1 ELEMENT STRESS REPRESENTATION

Given the data from the "elesol" file, which contains 9 stress values and 3 user-defined quantities for each function node of the element, the level of stress is displayed directly on the face of an element.

Points generated in the "elesol" file may be either 1/6 or 1/10 of the way from the boundary of the element. Interpolation naturally takes this into account obtaining from the libCode attribute in the *geom2.dat* file. There are basically three types of element stress representations:

Non-Conforming: Using all of the function nodes, the stress is "painted" over a mesh representing the element. The mesh size is user definable.

Conforming: The stress level for each node on the boundary of an element is determined by averaging the center values of all adjacent elements. The element is then painted to show the resulting contours.

Center Value: The element is simply painted with an appropriate colour to indicate the level of stress at the center of the element.

10.7.2 PLANAR STRESS REPRESENTATION

Viewing stress within a 3-dimensional object requires special consideration. VIEWBEAP uses "result regions" and "result planes" to view stress on planar surfaces within a volume of material. The result regions are volumes for which the stress levels within have been obtained. The determination of these results is somewhat complicated and discussed in more detail for the DIVIDE program. The result planes are rectangular surfaces located within one or more result regions. The stress levels on these planes are determined by interpolating the available data for the result regions. For more information on how to create and view result regions and result planes, refer to Sections 7 thru 9.

10.7.3 POINT STRESS REPRESENTATION

The following section discusses the procedure to find the level of stress at a specific point within the model. Point stresses can be found from within the Result Regions and Result Planes Windows (Sections 7 and 8). Activating the feature will produce a set of red cross-hairs as well as the following dialogue box:

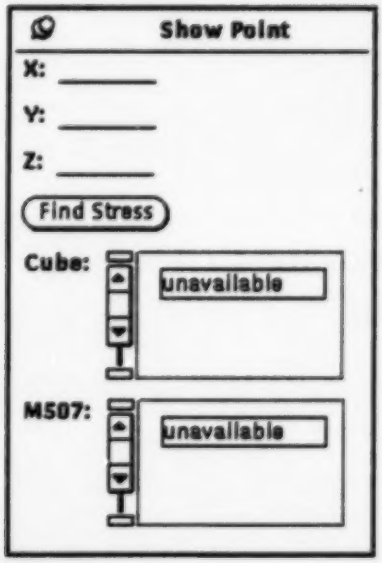


Fig 10.1 - Calculating Stress for a Specified Point

The cross-hairs will indicate graphically the point to be considered.

There are two options available for the user to find the stresses at a specified point in a boundary element model. If a result region for the model exists, then the stresses at the specified point will be interpolated using the existing stress information. As well, the

stresses at the specified point will be calculated by the M507 module, providing this module was activated when the user started the program (refer to Section 2).

The following procedure is suggested for the user to find the stresses at a specified point:

- Move the mouse pointer to a location on the screen where the user wishes to have the stresses calculated,
- Click on the point and drag the mouse (without releasing the mouse button); the x, y and z coordinates on the dialogue box will change while you drag the mouse; release the mouse button if you are satisfied with the location (coordinates) shown in the dialogue box,
  - or -
  the user can directly edit the coordinates which appear in the dialogue box,
- Click on the **find stress** button.

If the result cube is available the detailed stress information for the specified point will be displayed at the lower portion of the dialogue box. The user can scroll various values by toggle on the scroll bar.

As mentioned above, if the module M507 has been activated the stress values will appear as well.

10.8 STEREOSCOPIC VISION

The Stereoscopic vision technique is a known concept in the motion picture industry. However, implementation of the method in the software applications was not available. The mathematical implementation of the concept is straightforward. It is based on separating the image into two each having one chromatic colour. For the implementation of VIEWBEAP these colours were selected to be Cyan and Red. A pair of filtering glasses which filter out all but one of the colours for each eye, allows the user to see different images in each eye.

The stereoscopic vision technique work for both solid and wireframe images. This option will not work for stress contours due to the monochromatic nature of the technique.

APPENDIX A

Example Run

The following provides a procedure for the user to run an example:

- Create a directory and copy over the data file
- Copy over the file message.be from Beap directory
- Run successively the following modules:
  M101 by typing : path/m101.e
  M201 by typing : path/m201.e
  M203 by typing : path/m203.e
  M401 by typing : path/m401.e
  M501 by typing : path/m501.e
  M502 by typing : path/m502.e
  M503 by typing : path/m503.e
  M504 by typing : path/m504.e
  M205 by typing : path/m205.e
- Run VIEWBEAP by typing path/viewbeap
  - display the result (stresses and displacements on the elements).
  - define one or more ResultCube.
- Run 'divide' for ResultCubes for each mining step.
- Run VIEWBEAP again to define ResultPlane(s) and to display results on the specified plane(s). The primary purpose of the routines are to geometrically subdivide a user-specified 3-D space for a 3-D boundary element model for the purpose of defining where stresses and displacements should be calculated. This is referred to as the ResultCube. A ResultCube is a 3-D block which is defined by the three coordinate axes. The defining of a ResultCube has been described previously.